Bundesministerium für Bildung und Forschung

Projektträger Jülich
Forschungszentrum Jülich GmbH

RACE TP 1.1

Rolle des tropischen Atlantiks für Klimaschwankungen im atlantischen Raum

Brandt, P., Dengler, M., Hummels, R., Herrford, J.
GEOMAR Helmholtz Zentrum für Ozeanforschung Kiel

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

In order to understand the role of the tropical Atlantic for climate variability in the Atlantic region, this subproject aims at investigating the variability of the western boundary current (WBC) system off Brazil as well as the Atlantic Meridional Overturning Circulation (AMOC) at 11°S.

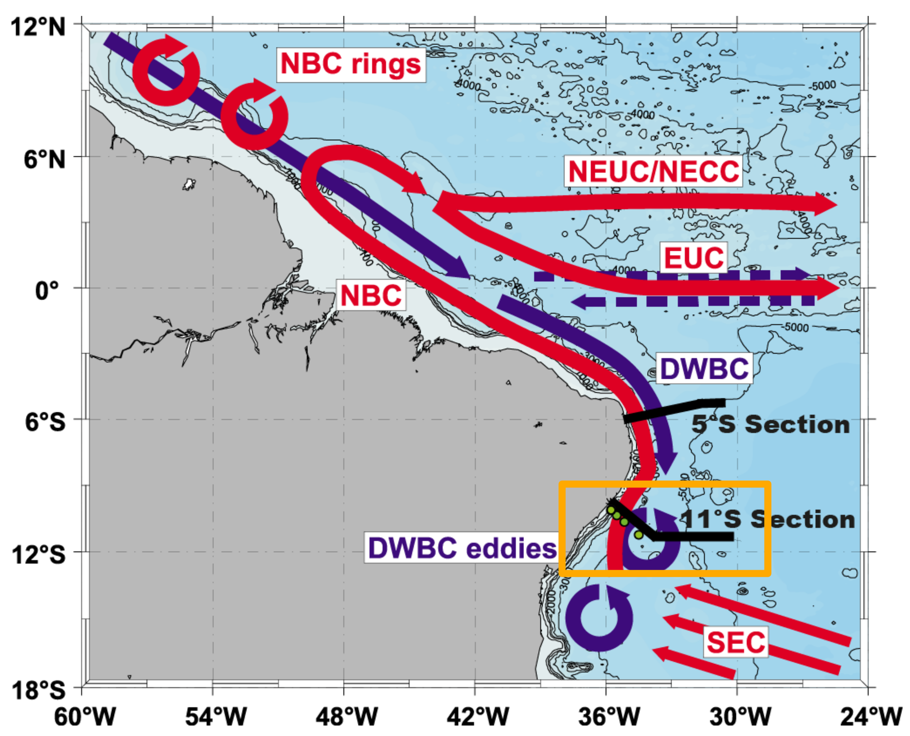


Fig. 1: Circulation scheme of the western tropical Atlantic (Dengler et al., 2004). Warm-(Cold) water routes of the AMOC are indicated in red (blue), hydrographic sections in black and moorings as green circles.

Observational program

- The WBC system is investigated with ship based observations and a mooring array (hydrographic as well as direct current observations).
- The variability of the WBC system, especially of the North Brazil Undercurrent (NBUC) and the Deep Western Boundary Current (DWBC) is investigated on time scales from intraseasonal to decadal.

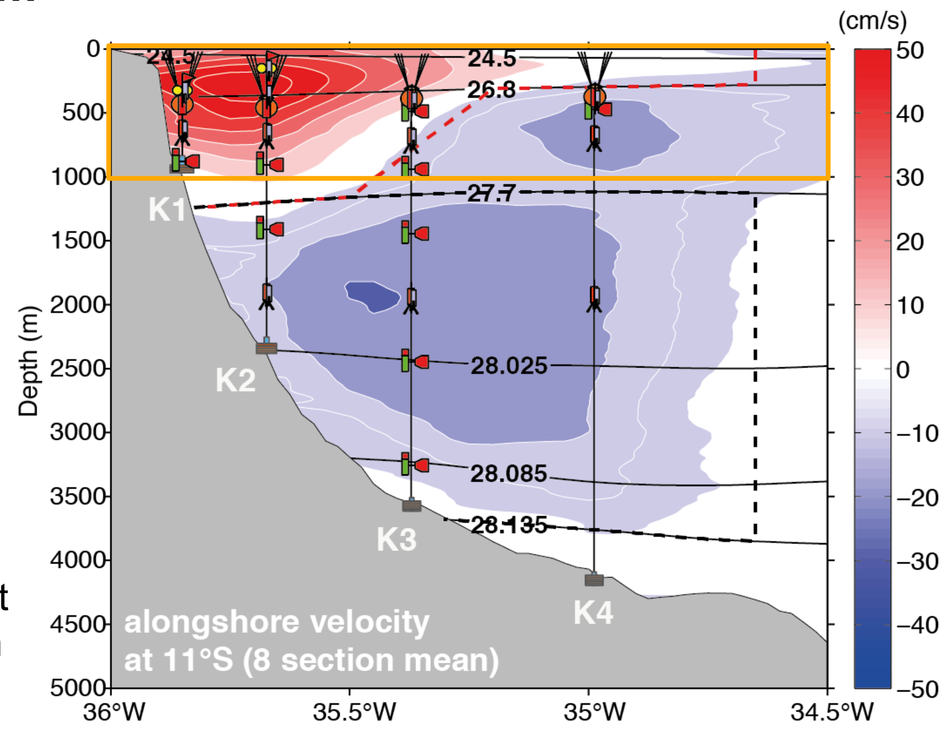


Fig. 2 Average section of alongshore velocity together with the moorings array design. Red/black dashed lines mark boxes for transport calculations (Fig.3).

- Deep Eddies, which have been shown to accomplish the transport of NADW instead of a laminar flow and were predicted to disappear with a weakening AMOC (Dengler et al. 2004) are still present with similar characteristic (Fig. 1,3).

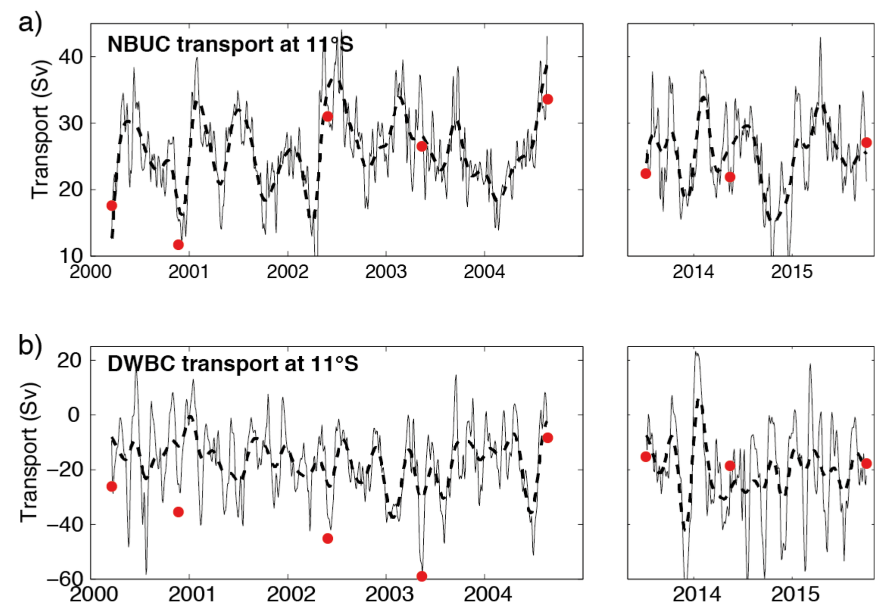
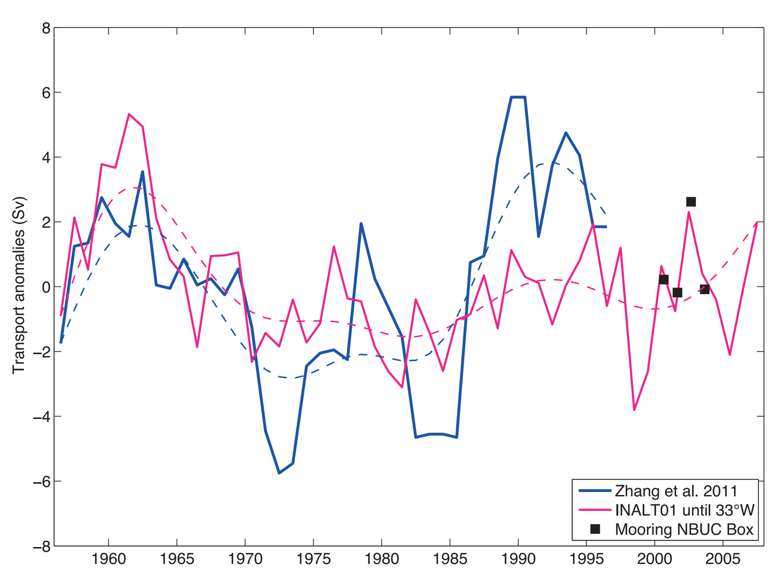


Fig. 3: Transport time series of the moored array for the NBUC (a) and DWBC (b). Red dots mark transports estimated from ship-board observations.

- Comparison of the recent cruises (2013, 2014 and 2015) with observations between 2000 and 2004 at the same location gives first insights into changes of currents and water mass properties on longer time scales.
- Additionally, the first two periods of moored observations could be recovered with an instrument performance of over 90%.
- The next cruises within RACE II are planned for 2016 and 2018.

Results from RACE I



- On longer timescales the variability of the NBUC and DWBC is reduced.
- On average moored observations do not show significant changes between the two observational periods.

(Sv)	2000-2004	2013-2015
NBUC	25.8±1.2	25.5±1.3
DWBC	-17±1.6	-20.5±2.7

Fig. 4: NBUC transport anomalies, where 15, 16 und 25 Sv were subtracted (INALT01, geostrophic transports and moored observations).

- Interannual NBUC variability as assessed from moored observations between 2000-2004 is consistently found in the output of a forced ocean model (INALT01).
- Decadal variability is similar in INALT01 and geostrophic transport estimates from Zhang et al. (2011).
- The observed decadal salinity increase in the central water range (100-600m) is consistent with previous estimates (Biastoch et al. 2009) as well as the interannual variability of salinity anomalies (Fig. 5a, Kolodziejczyk et al. 2014).
- The inferred vertical structure of salinity and oxygen trends (Fig. 5c, d) can be related to changes in water mass formation regions as well as circulation changes in remote regions of the Atlantic.

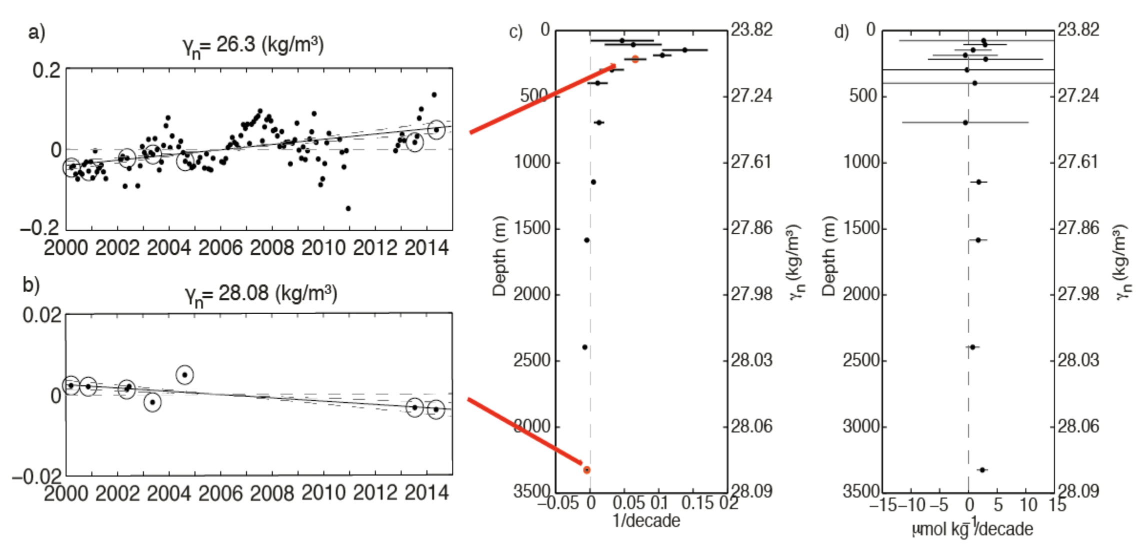


Fig. 5: Time series of salinity anomalies on neutral density surfaces (a,b) and the resulting salinity as well as oxygen trends as a function of depth/density (c,d).

Plans for RACE II

1. **Determine the mean, and seasonal to interannual variability of the AMOC at 11°S by constructing a transport time series.**

The AMOC is calculated by the sum of four meridional flow components (*Kanzow et al., 2010; Chidichimo et al., 2010*):

$$T_{AMOC}\,(t) = T_{MO}\,(t) + T_{EK}\,(t) + T_{WB}\,(t) + T_{EB}\,(t)$$

2. Use the INALT01 model configuration for comparison and completion of the resulting AMOC transport time series at 11°S.
3. Synthesize the results with other transport time series for an consistent picture of the tropical Atlantic circulation and for the investigation of meridional coherence in AMOC transport fluctuations.

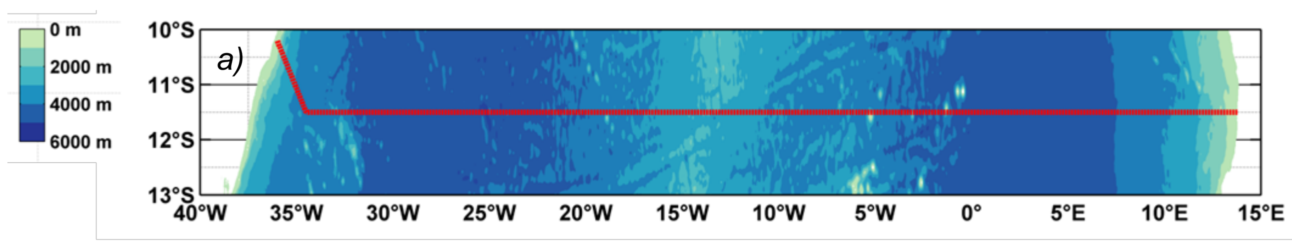


Fig. 7: a) ETOPO1 bathymetry with the location of the 11°S ship section (red line). (b, c) Schematic summarizing all measurements that will be used to quantify individual AMOC components along 11°S.

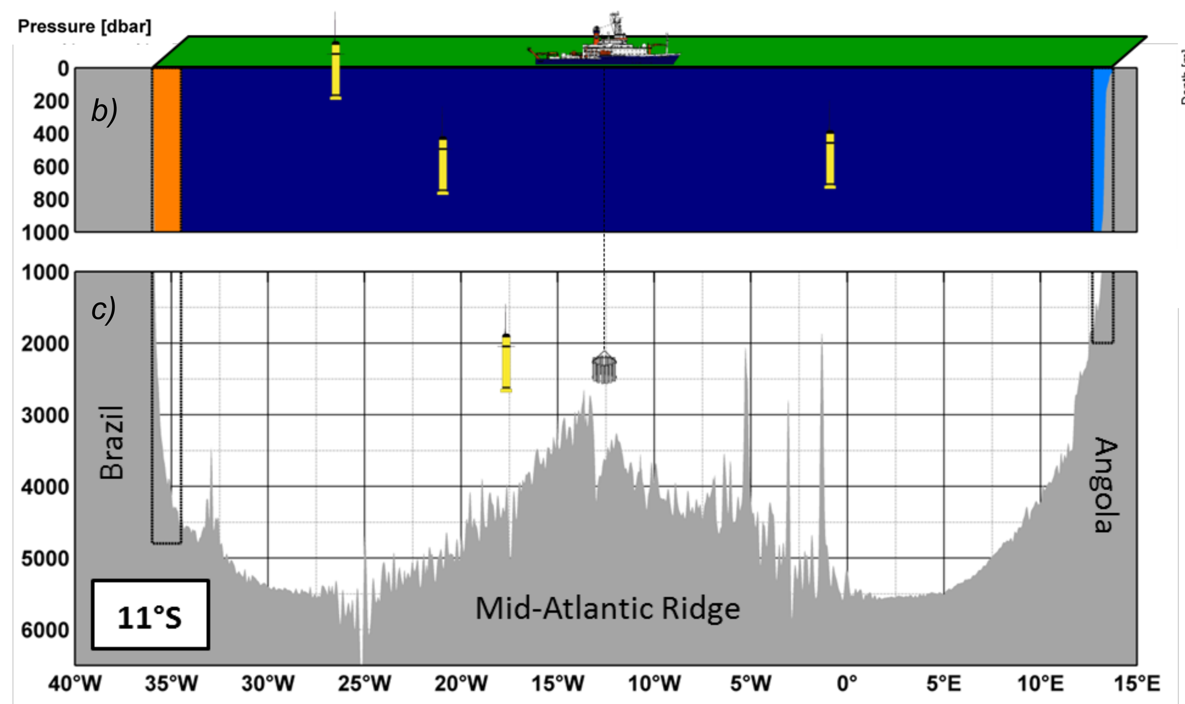
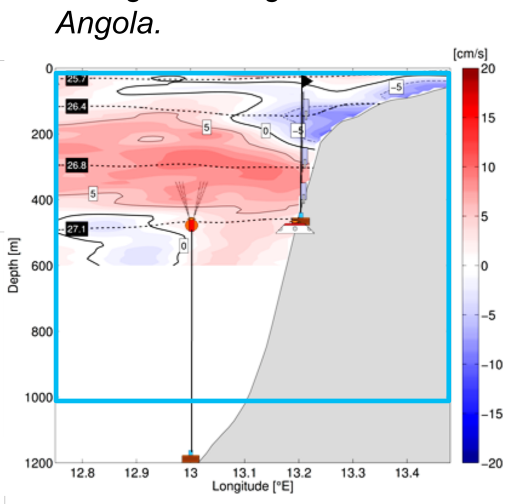


Fig. 8 Section of alongshore velocity (July 2013) together with the mooring array design along 11°S off Angola.



Ekman transport T_{EK}:
Comparison of different wind products and observations (NOAA-NCDC, ERA-INTERIM, NCEP-NCAR, ECMWF, CCMP, PIRATA)
(Fu, Karstensen & Brandt, in prep.)

Western boundary contribution T_{WB}:
Extension and validation of transport time series for the NBUC and DWBC at 11°S , as well as using a geostrophic approach, with:

- ship based CTD and ADCP observations
- moored current meter measurements (2000 - 2004, 2013 - 2018)

(Schott et al., 2005; Hummels et al., 2015)

Geostrophic mid-ocean component T_{MO}:
Determination of an interior geostrophic transport time series for the upper 1000 m at 11°S with:

- sea surface height from satellite altimetry or PIES installed on both sides of the Atlantic basin
- geostrophic transports from ARGO and ship based hydrography
- meridional velocities at 1000 m from ARGO floats

(Willis & Fu, 2008; Willis, 2010)

Eastern boundary contribution T_{EB}:
Quantification of the eastern boundary contribution to the AMOC transport variability at 11°S with:

- ship based CTD and ADCP observations
- moored current meter measurements (2013 - 2018)
- AVISO geostrophic velocity

(Chidichimo et al., 2010)

Aims RACE II

- **Assessment of the transport variability of NBUC, DWBC und the AMOC at 11°S on intraseasonal to decadal time scales.**
- **Investigation of the relation between transport variability at the western boundary at 11°S (warm and cold water route) and the variability in the subpolar North Atlantic with respect to signal propagation within the AMOC.**
- **Analysis of the spreading of water mass anomalies within the AMOC, which can e.g. originate from the variability in the inflow of saline waters from the Indian to the Atlantic ocean.**
- **Investigation of the relation between NBUC variability at 11°S and EUC variability at 23°W and its impact on the heat and freshwater balance of the mixed layer, the resulting ocean-atmosphere interactions and rainfall variability over West Africa.**

1) Biastoch, A., C. W. Boning, F. U. Schwarzkopf, and J. R. E. Lutjeharms (2009), Increase in Agulhas leakage due to poleward shift of Southern Hemisphere westerlies, Nature, 462(7272), 495-498, doi:10.1038/nature08519
2) Chidichimo, M. P., T. Kanzow, S. A. Cunningham, W. E. Johns, and J. Marotzke, 2010: The contribution of eastern-boundary density variations to the Atlantic meridional overturning circulation at 26.5°N. Ocean Sci., 6, 475–490, doi: 10.5194/os-6-475-2010.
3) Dengler M., F. A. Schott, C. Eden, P. Brandt, J. Fischer, and R. J. Zantopp (2004), Break-up of the Atlantic deep western boundary current into eddies at 8 degrees S, Nature, 432(7020), 1018-1020, doi: 10.1038/nature03134
4) Fu, Y., J. Karstensen, and P. Brandt, 2016: Meridional Ekman transport in the tropical Atlantic. *In preparation.*
5) Hummels, R., P. Brandt, M. Dengler, J. Fischer, M. Araujo, D. Veleda, and J. V. Durgadoo, 2015: Interannual to decadal changes in the western boundary circulation in the Atlantic at 11°S, Geophys. Res. Lett., 42, doi: 10.1002/2015GL065254.
6) Kanzow and Coauthors, 2010: Seasonal variability of the Atlantic meridional overturning circulation at 26.5°N. J. Climate, 23, 5678–5698, doi: 10.1175/2010JCLI3389.1.
7) Kolodziejczyk, N., G. Reverdin, F. Gaillard, and A. Lazar (2014), Low-frequency thermohaline variability in the Subtropical South Atlantic pycnocline during 2002–2013, Geophysical Research Letters, 41(18), 2014GL061160.
8) Schott, F. A., M. Dengler, R. Zantopp, L. Stramma, J. Fischer, and P. Brandt, 2005: The shallow and deep western boundary circulation of the South Atlantic at 5°–11°S, J. Phys. Oceanogr., 35, 2031–2053, doi:10.1175/JPO2813.1.
9) Willis, J. K., 2010: Can in situ floats and satellite altimeters detect long-term changes in Atlantic Ocean overturning? Geophys. Res. Lett., 37, L06602, doi: 10.1029/2010GL042372.
10) Willis, J. K., and L.-L. Fu , 2008: Combining altimeter and subsurface float data to estimate the time-averaged circulation in the upper ocean, J. Geophys. Res., 113, C12017, doi:10.1029/2007JC004690.

Abschlussseminar RACE und Auftakt RACE II, 30.3.2016, MARUM, Universität Bremen

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Max-Planck-Institut für Meteorologie

Universität Bremen

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE